Fosland, Robinson & Smith

A Study of a Small Suction Gas Producer

Mechanical Engineering

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A STUDY OF A SMALL SUCTION GAS PRODUCER

BY

Gerard Leonard Fossland
Raymond Elder Robinson
Ellis Edwin Smith

THESIS FOR THE DEGREE OF BACHELOR OF SCIENCE
IN MECHANICAL ENGINEERING

IN THE
COLLEGE OF ENGINEERING
OF THE
UNIVERSITY OF ILLINOIS
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UNIVERSITY OF ILLINOIS

June 1, 1908

THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

GERARD LEONARD FOSSLAND RAYMOND ELDER ROBINSON ELLIS EDWIN SMITH

ENTITLED A STUDY OF A SMALL SUCTION GAS PRODUCER

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science in Mechanical Engineering

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HEAD OF DEPARTMENT OF Mechanical Engineering

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TABLE OF CONTENTS.

Page.

I. Introductory, ... 1.

II. Method of Conducting Tests.

General Method,. . . . . 2.

Starting and Stopping, ... 2.

Fuel and Ash,. . . . . 3.

Gas Measurement, ... 3.

Analytical Discussion,. . . . . 4.

Calibration of Gaging Box,. . . . . 5.

Analysis and Calorific Value of Gas, . . . 8.

Jacket-Water,. . . . . 9.

Scrubber-Water,. . . . . 9.

Temperatures,. . . . . 10.

Pressures, ... 10.

Blower,. . . . . 10.

III. Arrangement of Apparatus, ... 12.

IV. Calculations and Corrections, ... 12.

Gas-Volume,. . . . . 12.

Heat-Value of Gas, ... 13.

Density of Gas,. . . . . 14.

V. General Discussion of Tests,. . . . . 15.

VI. Forms for Recording Data, ... 17.

VII. Data and Results.

Log Sheets,. . . . . 22.

Average Results, ... 26.

Graphical Logs,. . . . . 27.

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A STUDY OF A SMALL SUCTION GAS-PRODUCER.

Introductory.- The work herein described was undertaken as preparation for a careful investigation of the principles of operation of a suction gas-producer. As the primary object of the proposed investigation was to study the producer, it was considered an unnecessary complication to run tests on the engine at the same time, if a plan somewhat similar to that followed in boiler-trials could be shown to be applicable. It was therefore decided to install a blower to secure the necessary draft, and discharge the gas without burning it in the engine, gaging the output of the producer by measurements of the volume and calorific value, and by chemical analysis of the gas, instead of by the power output of an engine or engines running on that gas as has been common practice. The reasons for this separation of a producer-plant into two parts were as follows:

(a) Increased convenience and simplicity.

(b) More complete control over all conditions of operation.

(c) Absence of trouble and delays at either end of the test due to irregular performance of the other part of the plant.

(d) Probable gain in accuracy of data and correct interpretations of results, brought about by narrowing the field of study and decreasing the number of conditions affecting the performance of the producer.

(e) More satisfactory measure of producer performance afforded by volume and heating value of gas delivered than by the power which one particular engine can make from that gas.

Consideration of cost, convenience in working up data, etc., and the necessity for some general basis of comparison made the development of a standard method of conducting producer-trials an imperative first step.

General Method.- The basic idea of the proposed standard test is, briefly, to measure the energy input and output, determine the true rating and efficiency and distribution of the losses, and make such auxiliary observations as may tend to throw light on the conditions of most economical operation.

Starting and Stopping the Test.- The producer should be fired and run for a time sufficient to bring the temperatures, pressures, and gas-quality to normal running condition. The fire should be well cleaned and poked, and the magazine filled with coal about five minutes before the time it is desired to start the run. The height of the coal in the producer and the density or "tightness" of the fuel bed should be carefully noted at the time of starting, the ash pit cleaned, and other observations (temperatures, pressures, etc.) taken as directed for the entire test.

At the end of the test the fire should be brought back to the same condition as at the start, clean and well opened up, with coal at the same level in the magazine and the ash-pit empty.

Fuel and Ash.- Coal should be weighed as fired, all coal fired after filling the magazine at the start and including that required to fill it at the finish being considered as burned in the test. Analyses and calorific determinations should be made the same as for a boiler trial.

Gas Measurement.- The satisfactory measurement of large volumes of gas is a matter of considerable difficulty. Recording meters of the ordinary type large enough to take care of 12000 cu. ft. per hr. are cumbersome and expensive, and are seldom reliable over any considerable range of temperature, pressure, or discharge. Other methods which are advocated by well-known authorities are the Pitot tube gage and orifices of various kinds. The first of these is supported by several investigators, but its use for measurements accurate within two or three per cent involves careful calibration of each arrangement of gage and piping, with little prospect of determining any constant or regularly variable coefficients which could be applied to more than one particular case. The work done by Mr. R. J. Durley at McGill University and reported in a paper presented before the American Society of Mechanical Engineers in December, 1905, entitled "On the Measurement of Air Flowing into the Atmosphere through Circular Orifices in Thin Plates and Under Small Differences of Pressure", has shown that plain orifices such as are used in hydraulic measurements can be used with a formula analogous to the hydraulic formula $V^2 = 2gh$, with a probable error of not more than one per cent for heads of not more than two or three percent of the total absolute pressure on the orifice.

The apparatus used in the tests herein reported is believed to be readily adaptable to the needs of any producer that it may be desired to test. It consists of a cast-iron box containing a diaphragm in which is a standard orifice, and provided with suitable means for determining the pressure and temperature of the gas and the drop in pressure through the orifice, as shown in Fig. 1. The formulae for weight and volume of gas flowing through are based on the following analysis.

Let w = velocity of flow through the orifice in ft. per sec.

h = drop in head (in feet of the fluid flowing) through the orifice.

Then

$$w = c\sqrt{2gh}, \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

where c is a coefficient taking into account the loss due to friction, eddy currents, etc.

But

$$h = \frac{P_1 - P_2}{\delta}.$$

P_1 and P_2 being the absolute pressures above and below the orifice in lb. per sq. ft., and δ the weight in pounds of 1 cu. ft. of gas.

Then

$$w = c\sqrt{2g\,(P_1 - P_2)/\delta}, \quad \ldots\ldots\ldots\ldots \quad (2)$$

Now if G = weight of gas flowing in. lb. per sec., and F = area of orifice in sq. ft.,

$$G = Fw\delta$$

$$= Fc\sqrt{2g\,(P_1 - P_2)\delta}, \quad \ldots\ldots\ldots\ldots \quad (3)$$

$$= Fc\sqrt{2g\,(P_1 - P_2)\Delta}\ \frac{P}{P_s} \cdot \frac{T_s}{T}$$

where

Δ = weight of 1 cu. ft. of gas at standard pressure and temperature.

P = absolute pressure in the orifice.

T = absolute temperature in the orifice.

P_S and T_S = standard pressure and temperature (absolute scale).

Then we may write

$$G = k\sqrt{(p_1 - p_2)\frac{P'}{T}}, \quad \ldots\ldots\ldots\ldots \quad (4)$$

in which

P′ = absolute pressure in inches of mercury.

T = absolute pressure in °F.

$p_1 - p_2$ = pressure-drop in inches of water.

$k = Fc\sqrt{2g(\frac{T}{P})\Delta m}$, m being the factor needed to convert $(P_1 - P_2)$ to $(p_1 - p_2)$.

From the calibration data on this gaging-box, the value of k appears to depend on the absolute pressure P′, as might reasonably be expected, since the only possible variable entering into k is c, which, as in hydraulic measurements, would probably be dependent on the total head or pressure. The apparatus was calibrated by means of air flowing through a system of piping, (Fig. 1), containing it and terminating in a gaging tank and orifice which had already been carefully calibrated, but could not be used for these measurements owing to the fact that, the gas being of a poisonous nature, the tank would have had to be located at an inconvenient distance from the producer. Fig. 1 shows the arrangement and indicates the readings which were taken, and Plate I gives the results of the calibration, showing the relation of the coefficient k to the absolute pressure on the orifice.

PLATE I.
CALIBRATION CURVE OF
GAGING-BOX.
-R.E.R.

PLATE I.

CALIBRATION CURVE OF

CASING - BOX.

-P.E.R.-

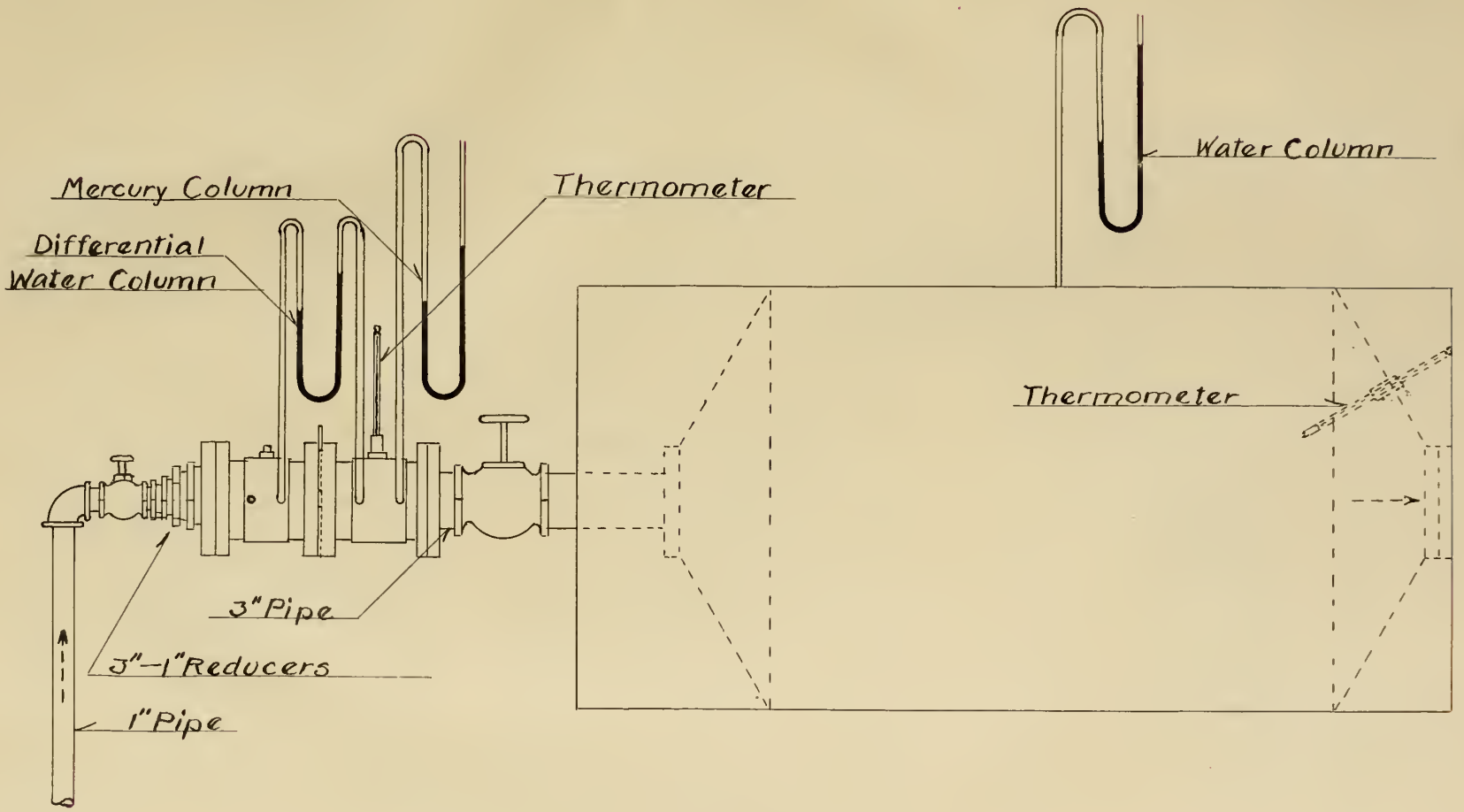

FIG. 1.

CALIBRATION OF GAGING-BOX. —R.E.R.

Assuming now that c is the same for all approximately perfect gases, it is evident that the value of k is proportional to $\sqrt{\Delta}$, Δ being the density of the given gas under standard conditions.

That is, if values of k are known for air, the value of k for any other gas is given by the relation

$$\frac{k_a}{k_g} = \sqrt{\frac{\Delta a}{\Delta g}}$$

or

$$k_g = nk_a \text{ , } \ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

where

$$n = \sqrt{\frac{\Delta g}{\Delta a}}$$

subscripts a and g referring to air and gas respectively.

It seems likely that by changing the proportions of the gage-box to eliminate as far as practicable the velocity of approach and approximate more closely the condition of atmospheric discharge, a more uniform variation of k would be secured, and Durley's and similar experiments could be more directly applied; but lack of sufficient time necessitated the postponement of such work for some future study.

Analysis and Calorific Value of Gas.- The gas will be analyzed by Hempel's method of volumetric determination, and the heating value calculated from the analysis, a second determination being made as a check by means of a Junkers Calorimeter.

The apparatus and connections for sampling the gas are shown in Fig. 2, the gas for the calorimeter samples being drawn from the pipe through a similar nozzle (the same as the standard nozzle for steam sampling). The pinch-cocks c and c′ are so

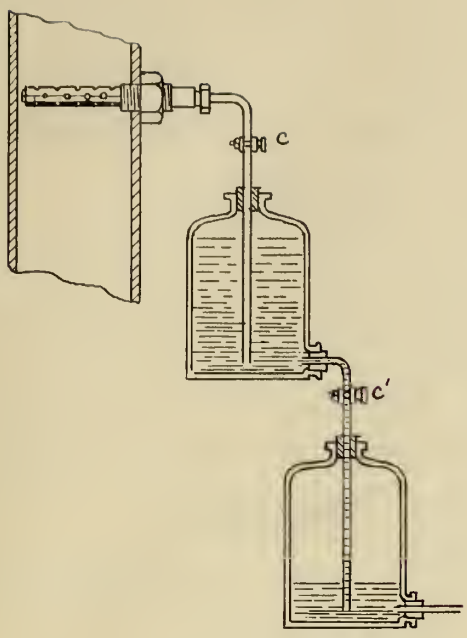

Fig. 2.

adjusted as to drain the bottle in any given time desired and thus give a sample covering that interval.

Jacket-Water.- The water in the jacket should be kept at a constant height by adjusting the supply so as to maintain a slight overflow, and the net weight of water determined by weighing both supply and overflow. A convenient arrangement for this purpose is shown in Fig. 3. From the weight of water evaporated and the weight and humidity of the air drawn into the jacket, the percentage of moisture in the blast as supplied to the fire may be readily calculated.

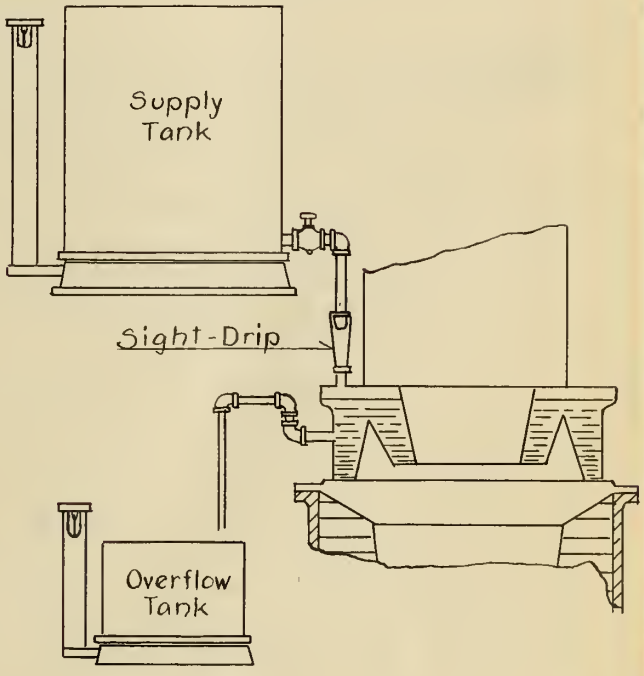

Fig. 3.

Scrubber-Water.- The most convenient method of measuring the water used in cleaning and cooling the gas is to use a meter placed in the supply pipe. Since the scrubber-water will pass continuously through the meter, at a velocity and pressure which are

practically constant for any one test, the meter may be calibrated and corrections made with little difficulty and considerable exactness.

Temperatures.- Temperatures will be taken at various places as indicated on the summary of results of the trial. Ordinary mercury thermometers, carefully calibrated, should be used except for the high fuel-bed and flue-temperatures, where thermo-couples will be necessary.

Pressures.- Since all the pressures are small they will be measured by means of manometers.

Blowers.- Where steam-pressure is available a steam ejector affords very satisfactory means of securing the desired draft, or if steam at a sufficient pressure is not to be obtained, a small rotary fan may be used.

Although for convenience, the aspirator in these tests was placed between the producer and scrubber, it should, of course, regularly be located beyond the scrubber so as not to introduce the uncertain factor of the quantity and heat content of the steam, which would vitiate, or at the best complicate very much, any data on the quantity of water used or heat lost in cleaning the gas. If a mechanical blower be used, its position is of less importance, but it also would be connected beyond the scrubber, both on account of the smaller volume of the gas after cooling and the consequent reduces size requirements of the fan, and because of the liability of the moving finished parts to injury from the high temperature and dust contained in the gas before it enters the scrubber.

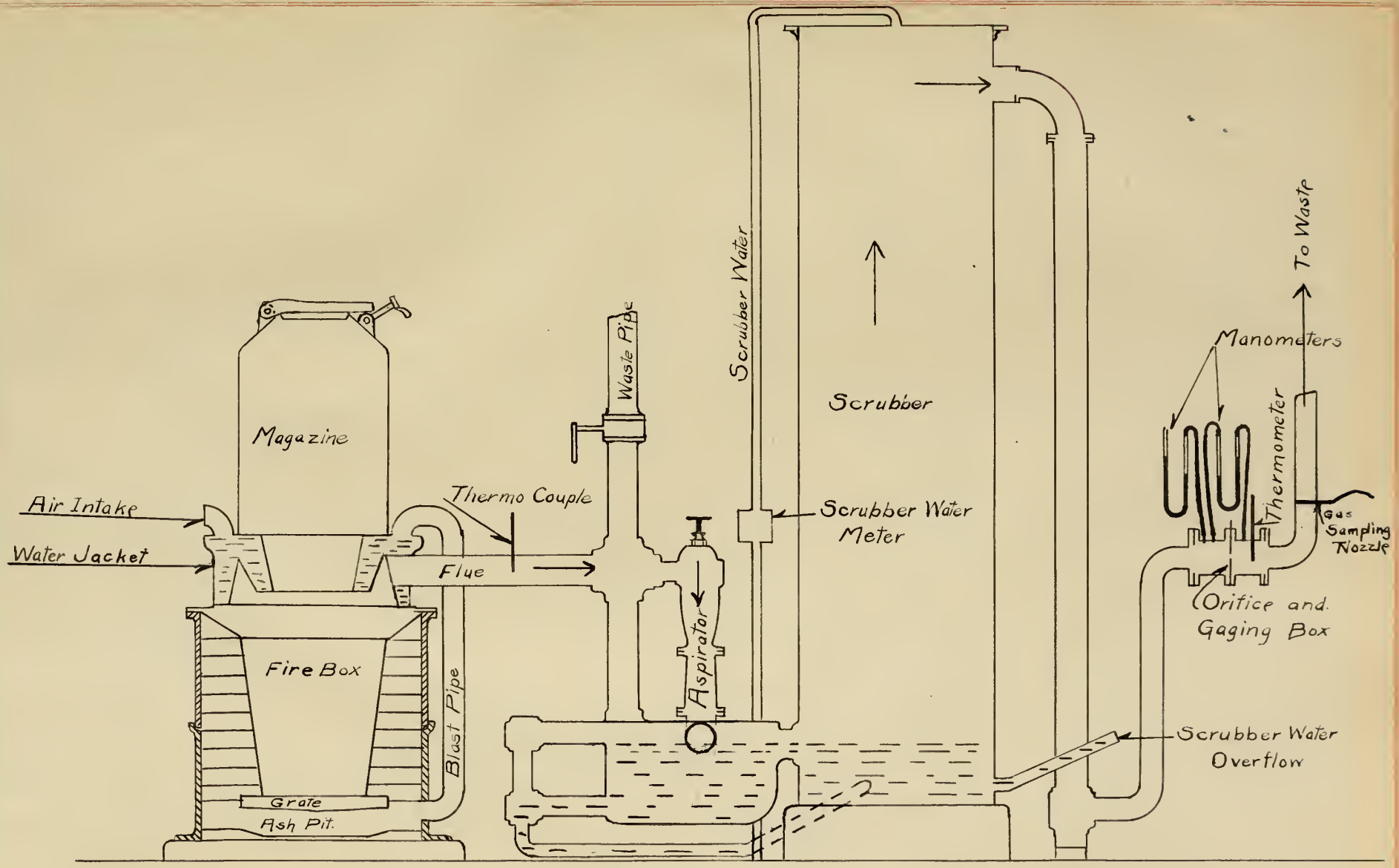

Fig. 4.

DIAGRAMMATIC SKETCH OF PRODUCER AND APPARATUS

Arrangement of Apparatus.– Fig. 4 shows diagrammatically the arrangement of the apparatus. The producer is of the standard Otto suction type, rated at 60HP, the only variation from the standard being the introduction of the steam ejector as indicated. Temperatures, pressures, and gas–samples were taken at places shown.

Calculations and Corrections.– All measuring instruments used in the four tests of this series were calibrated and the requisite corrections applied to their readings.

Calculation of gas–volume.– From the formulae 4 and 5 derived under "Gas–Measurement" we have

$$G_g = k_g \sqrt{(p_1 - p)_2 \frac{P'}{T}} = nk_a \sqrt{(p_1 - p_2) \frac{P'}{T}}.$$

The discharge in standard cubic feet per hour

$$= V_g = \frac{3600g}{\Delta_g} = \frac{3600nk_a}{\Delta_g} \sqrt{(p_1 - p_2) \frac{P'}{T}}$$

Then

$$V_g = Ak_a \sqrt{(p_1 - p_2) \frac{P'}{T}}, \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

Where $A = \frac{3600\ n}{\Delta_g}$, and may, without serious error, be assumed constant for any one test, while k_a is a coefficient obtained from the calibration of the gaging box, which is given on page 6.

Thus for Reading No. 10, Test No. 3;

k_a (corresponding to 34.07 in. of mercury) = .3458

n (for the whole test) = .964

$$A = \frac{3600n}{\Delta_g} = \frac{3600 \times .964}{.0706} = 49160$$

$$V_g = A\ K_a \sqrt{(p_1 - p_2) \frac{P'}{T}} = 49160 \times .3458 \sqrt{.75 \times \frac{34.07}{527.1}}$$

$$= 3741 \text{ st'd cu. ft. per hr.}$$

Calculation of heating value of gas.- Assume the following notation:

In a Junker's Calorimeter,

T_g = absolute temperature of gas in meter, °C.

P_g = absolute pressure of gas in meter, inches of mercury.

t = difference of temperature of cooling water at entrance and exit, °C.

W = cooling water, liters.

V_g = meter reading, cubic feet.

T_s, P_s, V_s, = corresponding quantities for gas under standard conditions (62° F., 30 inches mercury).

H = heating value of gas, B.T.U per st'd cu. ft.

H' = heating value of gas, cal. per st'd cu. ft.

3.968 = constant to change from calories to B.T.U.

Then

$$H' = \frac{Wt}{V_s}$$

$$H = \frac{3.968\ Wt}{V_s}$$

But

$$V_s = \frac{V_g\ P_g\ T_s}{P_s\ T_g}$$

$$\therefore H = \frac{3.968\ Wt\ P_s T_g}{V_g P_g T_s}$$

We may write for this

$$H = K\frac{T_g\ t}{V_g\ P_g}$$

where

$$K = \frac{3.968\ W\ P_s}{T_s}$$

Now from the conditions of operating the calorimeter,

$$W = 8$$

and

$$P_S = 30, \quad T_S = 289.65$$

Therefore

$$K = \frac{3.968 \times 8 \times 30}{289.65} = 3.295$$

Therefore

$$H = \frac{3.295\ T_g t}{V_g\ P_g}$$

For Reading No. 10, Test No. 3;

$$H = \frac{3.295\ (289.65 + 27)(23.52 - 18)}{1.61\ (29.32 + 3 \times .0736)}$$

$$= 115 \text{ B.T.U. per standard cubic foot.}$$

To determine the heat value of the gas from its chemical composition, multiply the per cent by volume of each combustible gas component by its heating value in B.T.U. per st'd cu. ft., and divide the sum of these products by 100. That is,

$$H = \frac{1670\ C_2H_4 + 342\ CO + 346\ H_2 + 1070\ CH_4}{100}$$

For Reading No. 10, Test No. 3;

$$H = \frac{1670 + 342 \times 19 + 346 \times 14.1 + 1070 \times 0}{100}$$

$$= 113.9 \text{ B.T.U. per st'd cu. ft.}$$

Calculation of Density of Gas.- The density of the gas is calculated from its analysis by means of the principle just used. Methods of calculating other items are indicated on the summarized sheet of test results.

$$\Delta = \frac{\Sigma \text{Per cent by volume} \times \text{density of given component}}{100}$$

For Test No. 3 the average analysis was

Component	CO_2	C_nH_{2n}	O_2	CO	H_2	CH_4	N_2
Percent by volume	9.45	.116	.85	20.66	10.436	.366	58.135
Density(St'd)	1.52	1.440	1.105	9.67	.069	.553	.97

$$= \frac{9.45 \times 1.52 + .116 \times 1.440 + .85 \times 1.105}{100}$$

$$\underline{+ 20.66 \times .967 + 10.436 \times .069}$$

$$100$$

$$= \frac{.366 \times .553 + 58.135 \times .97}{100} = .928$$

General Discussion of Tests.- The principal value of the present tests lies in their bearing on the subject of methods of testing producers. A review of the logs and average results, it is true, leads to a few general conclusions such as that uniformity of firing is of the first importance as affecting the quality of the gas; that the producer should be opened at top or bottom as seldom as it is consistent with the necessity for a clean, open fire; that the amount of water evaporated in the jacket by its effect on the moisture of the blast, affects the hydrogen content of the gas to a considerable extent; that the efficiency of combustion is increased by decreasing the frequency of cleaning the grate (although if there were some means provided for grinding down the ashes uniformly, without admitting air directly under the grate, this might not be true). These statements, however, are pretty generally accepted, and the real value of the four runs, data and results of which follow, lies in the fact that they have shown the proposed standard method of conducting suction-producer trials to be readily applicable to ordinary commercial testing, and peculiarly advantageous for special investigation on account of the ease with which single items can be varied without affecting the other running conditions.

Note.- The position of the aspirator made it impracticable to obtain any check on the heat lost in the scrubber, and therefore, as very little time was available all idea of making even a partial heat-balance for these tests was abandoned, although in ordinary circumstances the heat balance is of considerable value and should be made.

The efficiencies given in the Results Sheet are cold-gas efficiencies. The hot-gas efficiencies were not determined because the sensible heat of the gas is lost when it is to be used in an engine, and the hot-gas efficiency is therefore of secondary importance in a test of this nature. Further, the efficiencies are based on the averages of the calorimetric determinations as shown on the logs of the several tests.

FORMS FOR RECORDING DATA.

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GAS-PRODUCER TRIAL.

Test No....

Date ..... Observer .....

WATER SHEET

INST. NO.

TIME	Jacket-Water				Scrubber-Water			Temperatures			
	Water in Feed-Tank	Water Delivered to Jacket	Overflow	Net Water Evaporated	Meter Reading	Difference	Net Water Used	Entering Jacket	Leaving Jacket	Entering Scrubber	Leaving Scrubber
	Pounds	Pounds	Pounds	Pounds	Liters	Liters	Pounds	°F.	°F.	°F.	°F.
1	2	3	4	5	6	7	8	9	10	11	

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GAS-PRODUCER TRIAL.

Test No....

FILE

Date ..... Observer .....

GAS SHEET

INST. NO.

TIME	Draft-Pressures		Temperatures			Pressure at Orifice	Temperature at Orifice.	Pressure-Drop through Orifice	Discharge Std Gas Cu.ft./hr.	Time of Calorimeter Determination	Calorific Value B.T.U./cu.ft.
	Under Grate	Over Fuel-Bed	Under Grate	Fuel Bed	Leaving Producer						
1	2	3	4	5	6	7	8	9	10	11	

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GAS-PRODUCER TRIAL

Test No.....

Date ..... Observer .....

COAL AND ASH SHEET

INST. NO.

TIME	Coal Delivered to Scale	Coal on Scale After Each Firing	Coal Fired	Cleaning Record		Time	Ash Taken Out	FUEL		
	Pounds	Pounds	Pounds				Pounds			
1	2	3	4	5	6	7	8	9	10	11

Moist Coal Consumed, Pounds

Moisture in Coal, %

Dry Coal Consumed, Pounds

Wood Consumed, Pounds

Coal Equivalent of Wood (= wood x 0.4), Pounds

Total Dry Coal, Including Wood Equivalent, Pounds

Total Dry Refuse, Pounds

" " " , %

Total Combustible, Pounds

DESCRIPTION OF FUEL

Commercial Name

Commercial Size

Lumps, %

Slack, %

Appearance

LOGS

AVERAGE RESULTS

AND

GRAPHICAL LOGS

No.	ENTS Analysis Gr./cu. ft.	DISCHARGE Standard Cu. Ft./Hr.	ANALYSIS CO_2	C_nH_{2n}	O_2	CO	H_2	CH_4	N_2
1									
2	13.0								
3									
4		5370							
5	?	5728							
6	17.0	6050							
7		5490							
8		6560							
9		6065							
10	?	4640							
11	32.0	6240							
12		5265							
13		5270							
14	34.0	5760							
15		5480							
16		4860							
17		5480							
18	4.3	6040							
19		6030							
	20.3	90328							
	14.0	5640							

OTTC SUCTION GAS PRODUCER – TEST No 1.

No	TIME	WATER			COAL and ASH				GAS																		
									TEMPERATURES			PRESSURES			HEAT CONTENTS		DISCHARGE	ANALYSIS									
		Evaporated in Jacket Lbs.	Scrubber water Meter Reading Liters	Water to Scrubber Lbs	Coal Delivered to Scale Lbs.	Coal Fired Lbs	Cleaning Record	Ash Taken Out Lbs	Leaving Producer °F	At Orifice °F	Room °F	At orifice ins Hg.	Drop through orifice ins H_2O	Barometer ins Hg	By Calorimeter BTU/cu ft	By Analysis BTU/cu ft	Standard Cu Ft/Hr	CO_2	C_nH_{2n}	O_2	CO	H_2	CH_4	N_2
1	11:55		335650				Poked Fire		580	76.0		5.85															
2	2:15		336620	2261			Poked Fire		660	66.5	68.3	5.75			1305	1430											
3	:35		337630	2360					720	63.0	67.2	5.56			1230												
4	:55		338670	2425			Poked Fire		580	63.0	71.2	5.45	1.35				5370										
5	3:15		339660	2310					720	62.5	71.7	4.60	1.50			?	5728										
6	:35		340730	2500			Poked Fire		760	60.5	64.1	4.60	1.70			1770	6050										
7	:55		341740	2360			Poked and Cleaned Fire		1168	61.0	64.7	4.60	1.40		1090		5490										
8	4:15		342725	2295			Poked Fire		810	60.5	63.7	4.90	2.00				6560										
9	:35		343708	2290			Poked Fire		1060	60.0	62.0	4.85	1.70				6065										
10	:55		344693	2295	175	175			937	61.0	63.7	4.90	1.00			?	4640										
11	5:15		345630	2200			Poked Fire		867	61.5	64.7	4.90	1.80	29.42		1820	6240										
12	:35		346550	2145			Poked and Cleaned Fire		1040	61.5	65.7	4.90	1.30		890		5265										
13	:55		347488	2188			Poked Fire		920	63.0	65.7	4.90	1.30	29.42			5270										
14	6:15		348470	2290			Poked and Cleaned Fire		860	64.0	65.7	4.90	1.55		875	1340	5760										
15	:35		349445	2265	100	100	Poked Fire		980	63.0	65.0	4.95	1.40		1237		5480										
16	:55		350445	2335			Poked and Cleaned Fire		883	62.0	64.7	4.95	1.10		1125		4860										
17	7:15		351438	2315			Cleaned Fire		830	62.5	63.7	4.95	1.40		1130		5480										
18	:35		352400	2245			Poked and Cleaned Fire		1000	61.0	63.7	4.95	1.70		1310	843	6040										
19	:55		353450	2450	170	149		150	865	64.0	64.7	5.05	1.70				6030										
				41529		424		150	16240	11965	11802	9551	2390		10192	7203	90328										
									854	63.0	656	5.02	1.49		1131	1440	5640										

	Standard Discharge c.v. Ft/Hr.	ANALYSIS						
		CO_2	C_nH_{2n}	O_2	CO	H_2	CH_4	N_2
	6340							
	5830							
	5640	6.8	0	0	21.4	15.7	0.4	55.7
	5480							
	6600							
	5840							
	5830	5.4	0	0.2	23.0	13.1	0.4	57.9
	6740							
	5780							
	6150							
	5090	9.6	0	0.1	20.0	17.3	0.4	52.6
	5840							
	5080							
1	5835	10.2	0	0.2	16.4	13.5	1.6	58.1
1	6000							
1	5830							
1	6000							
1	5805	10.2	0	0.4	17.7	15.0	0.4	53.3
1	5830							
2	5460							
2	6160							
2	5650							
2	5080							
2	4460							
2								
Av.	5760	8.44	0	0.18	19.7	14.9	0.64	55.5

OTTO SUCTION GAS PRODUCER — TEST NO. 2

No	TIME	WATER			COAL and ASH				TEMPERATURES			PRESSURES			HEAT CONTENTS		Standard Discharge	ANALYSIS						
		Evaporated in Jacket Lbs	Scrubber Water-Meter Reading Liters	Water to Scrubber Lbs	Coal Delivered to Scale Lbs	Coal Fired Lbs	Cleaning Record	Ash Taken Out Lbs	Leaving Producer °F	At Orifice °F	Room °F	At Orifice ins Hg	Drop through Orifice ins H_2O	Barometer ins Hg	By Calorimeter BTU/cu Ft	By Analysis BTU/cu Ft	cu Ft/Hr	CO_2	C_nH_{2n}	O_2	CO	H_2	CH_4	N_2
1	0 15		358750						740	600	605	46	2.0				6340							
2	35		359520	1795					938	593	605	45	1.7		970		5830							
3	55		360295	1810			Poked and Cleaned Fire		960	587	61.5	42	1.6			1316	5640	6.8	0	0	21.4	15.7	0.4	55.7
4	10 15		361185	2075			Cleaned Fire		620	58.7	61.5	44	1.5		1135		5480							
5	35	4.00	361880	1620			Cleaned Fire		938	58.7	61.5	40	2.2				6600							
6	55	8.13	362675	1855			Cleaned Fire		1010	587	61.5	42	1.6		1322		5840							
7	11 15	28.56	363460	1830	100	100	Poked and Cleaned Fire		790	593	61.5	44	1.7		1247	1282	5830	5.4	0	0.2	23.0	13.1	0.4	57.9
8	35	31.81	364240	1820			Cleaned Fire		1060	593	62.5	41	2.3				6740							
9	55	21.94	365020	1820					1090	593	62.5	3.8	1.7		1298		5780							
10	12 15	27.00	365815	1855			Poked and Cleaned Fire		960	593	62.5	42	1.9				6150							
11	35	15.55	366655	1960					1060	587	62.5	43	1.3	29.54	1270	1326	5090	9.6	0	0.1	20.0	17.3	0.4	52.6
12	55	19.14	367750	2555			Cleaned Fire		1010	587	62.1	47	1.7				5840							
13	1 15	0.00	368575	1925					1000	587	64.1	42	1.3	29.52			5080							
14	35	11.38	369420	1970	200	200	Poked and Cleaned Fire		860	587	62.5	46	1.7		1215	1200	5835	10.2	0	0.2	16.4	13.5	1.6	58.1
15	55	33.00	370275	1995					1120	587	64.7	45	1.8		1300		6000							
16	2 15	32.50	371160	2065			Cleaned Fire		1190	587	64.1	44	1.7				5830							
17	35	24.25	372030	2030					1100	593	65.0	45	1.8				6000							
18	55	19.31	372920	2075					1218	593	65.0	43	1.7		1195	1168	5805	10.2	0	0.4	17.7	15.0	0.4	53.3
19	3 15	13.25	373675	1760			Poked Fire		1110	60.0	63.7	44	1.7				5830							
20	35	17.56	374485	1890					1218	60.0	63.7	42	1.5		1090		5460							
21	55	30.00	375310	1925			Poked and Cleaned Fire		740	60.0	63.7	47	1.9				6160							
22	4 15	29.62	376110	1865					1040	593	64.1	5.0	1.6			Sample Lost	5650							
23	35	6.06	376950	1960	400	400	Poked Fire		1140	60.0	66.8	5.1	1.3		1330		5080							
24	55	28.50	377810	2005					980	60.5	67.8	5.0	1.0				4460							
25	5 15	20.81	378700	2075	115	115	Poked Fire	1495		68.7														
AVERAGE OR TOTAL		416.37		46535		815		1495	995	596	63.2	4.46	1.67		1215	1257	5760	8.44	0	0.18	19.7	14.9	0.64	55.5

No.	Standard Discharge Cu. Ft./Hr.	ANALYSIS							
		CO_2	C_nH_{2n}	O_2	CO	H_2	CH_4	N_2	
1	4525								
2	4989	7.6	0	0.3	20.3	11.0	0	60.5	
3	4940								
4	5380								
5	5270								
6	5352	5.0	0	0.5	24.6	11.0	0.6	58.3	
7	5200								
8	4855								
9	4635								
10	3741	8.8	0	1.1	19.0	14.1	0.0	57.0	
11	4429								
12	4270								
13	5365								
14	5558	10.2	0	1.6	13.5	11.0	0.4	63.3	—?
15	4405								
16	5198								
17	4330								
18									
19									
20									
21		12.3	0	0.7	14.7	7.2	1.2	63.9	
22									
23									
24		12.8	0.7	0.9	11.2	8.3	0.0	63.8	
25									
AVER TO	4850	9.45	0.11	0.85	17.2	10.46	0.36	61.1	

OTTO SUCTION GAS PRODUCER — TEST NO 3.

NO	TIME	WATER: Evaporated in Jacket — Lbs	WATER: Scrubber Water-Meter Reading Liters	WATER: Water to Scrubber — Lbs	COAL and ASH: Coal Delivered to Scale Lbs	COAL and ASH: Coal Fired — Lbs	COAL and ASH: Cleaning Record	COAL and ASH: Ash Taken Out Lbs	GAS: TEMPERATURES: Leaving Producer °F	TEMPERATURES: At Orifice °F	TEMPERATURES: Room °F	GAS: PRESSURES: At Orifice ins Hg	PRESSURES: Drop through Orifice ins H_2O	PRESSURES: Barometer ins Hg	GAS: HEAT CONTENTS: By Calorimeter BTU/Cu Ft	HEAT CONTENTS: By Analysis BTU/Cu Ft	Standard Discharge Cu Ft/Hr	ANALYSIS: CO_2	ANALYSIS: C_nH_{2n}	ANALYSIS: O_2	ANALYSIS: CO	ANALYSIS: H_2	ANALYSIS: CH_4	ANALYSIS: N_2
1	0 20	0 0	382900				Poked and Cleaned Fire		1020	661	780	440	1.00				4525							
2	40	5 0	383533	1478					1011	66.1	760	480	1.35		1138	107.6	4989	76	0	0 3	20 3	11 0	0	60 5
3	11 00	46	384288	1760					980	651	76.0	505	1.30				4940							
4	20	90	384945	1535			Poked Fire		980	656	765	510	1.55				5380							
5	40	80	385630	1600					989	702	77.0	5.10	1.50				5270							
6	12 00	100	386335	1645					989	70.2	77.0	505	1.55		1193	1285	5352	50	0	0 5	24 6	11 0	0.6	58 3
7	20	226	387040	1645					996	69.1	77.5	505	1 50		1090		5200							
8	40	88	387760	1680	100	100	Poked Fire		1208	666	785	4.95	1.30				4855							
9	1 00	94	388475	1670					900	661	785	485	1.15				4635							
10	20	155	389175	1633					980	661	785	475	0 75		1150	113.9	3741	88	0	11	19 0	14.1	0 0	57 0
11	40	100	389845	1560					1040	672	785	4.70	1.05		1225		4429							
12	2.00	159	390520	1575					1200	727	775	425	1.00	29.32	1093		4270							
13	20	140	391180	1540					1240	820	785	435	1.60		1550		5365							
14	40	169	391830	1515					1278	915	765	425	1.65			887	5558	10 2	0	1.6	13 5	11 0	0.4	63 3 — ?
15	3 00	140	392465	1480	100	100	Poked Fire		900	1130	750	405	115		1380		4405							
16	20	130	393122	1533					1180	850	750	465	150		1320		5198							
17	40	275	393785	1548					1247	905	736	460	1.05		1565		4330							
18	4 00	134	394440	1528					1208	825	731	4.65			1450									
19	20	168	395125	1600					1400	739	740	450	Water in Tubing											
20	40	187	395780	1528	100	100	Poked Fire		1520	955	731	443												
21	5 00	253	396435	1528					1040	1012	722	440				893		12.3	0	0 7	14 7	7 2	1 2	63 9
22	20	155	397095	1540					1240	850	70.0	445												
23	40	139	397770	1572					1380	760	71.2	440			86.5									
24	6 00	172	398462	1612					1481	79.0	694	435				78.9		12.8	0 7	0 9	11 2	8.3	0.0	63 8
25	20	193	399170	1650	200	200	Poked and Cleaned Fire	39.5	1240	75.0	694	450												
AVERAGE OR TOTAL		3453		37955		500		39.5	1145	77.6	752		1.29				4850	9 45	0.11	0 85	17.2	10 45	0.36	61.1

No	Standard Discharge Cu. Ft/Hr.	ANALYSIS						
		CO_2	C_nH_{2n}	O	CO	H	CH_4	N
1	5930							
2	5250							
3								
4								
5		7.0	0	0	24.6	13.7	0	34.7
6								
7								
8	6470							
9	5805							
10	5665							
11	5665	7.2	0	0	22.7	19.0?	0	48.9
12	5320							
13	5980							
14	5965							
15	5865							
16	5770							
17	5665							
18	5760	8.1	0	.4	22.5	12.6	0	56.4
19	5620							
20	5250							
21	5250							
22	6035	9.2	0	0	18.4	14.4	0	5.8
23	5720							
24	4675							
25	5770	8.0	0	0	22.4	9.9	0	58.5
AVE TOT	5670	7.9	0	.08	22.1	13.9	0	51.3

OTTO SUCTION GAS PRODUCER – TEST No 4

No	TIME	WATER: Evaporated in Scrubber – lbs	WATER: Scrubber Water Meter Reading – ft³	WATER: Water to Scrubber – lbs	COAL and ASH: Coal Delivered to Scale – lbs	COAL and ASH: Coal Fired – lbs	COAL and ASH: Cleaning Record	COAL and ASH: Ash Taken Out Lbs	GAS: TEMPERATURES: Leaving Producer °F	TEMPERATURES: At Orifice °F	TEMPERATURES: Room °F	PRESSURES: At Orifice ins Hg	PRESSURES: Drop through orifice ins H_2O	PRESSURES: Barometer ins Hg	HEAT CONTENTS: By Calorimeter BTU/cu Ft	HEAT CONTENTS: By Analysis BTU/cu Ft	Standard Dry Gas Cu Ft/Hr	ANALYSIS: CO_2	ANALYSIS: C_nH_{2n}	ANALYSIS: O	ANALYSIS: CO	ANALYSIS: H	ANALYSIS: CH_4	ANALYSIS: N
1	9:40		406155	1785			Cleaned Fire		1092	88.5		5.1	1.9				5930							
2	10:00	7.50	406920	1722					1092	92.6		5.3	1.5				5250							
3	:20	10.50	407958	1753					1110	106.0	59.6	5.3	0.7											
4	:40	9 00	408410	1680					1165	114.0	62.5	5.5	0.5		109.7									
5	11:00	11.25	409130	1750					1160	115.9	62.0	5.6	0.5			131.5		7.0	0	0	24.6	13.7	0	34.7
6	:20	11.75	409880	2550					1200	111.5	60.5	5.8	0.3		132.7									
7	:40	13.00	410975	1680						75.0					112.7									
8	12:00	14.50	411695	2435					1248	68.0	62.5	2.6	2.25				6470							
9	:20	17.00	412740	2625			Cleaned and Poked Fire		1297	64.0	62.5	2.6	1.8		116.3		5805							
10	:40	8.00	413865	2650					920	61.0	61.5	2.7	1.7				5665							
11	1:00	8.00	414995	2628	230	200			1100	60.0	62.5	2.7	1.7		112.7	143.0?	5665	7.2	0	0	22.7	19.0?	0	48.9
12	:20	11.50	416090	2400					1180	60.0	60.5	2.7	1.5				5320							
13	:40	10.00	417120	2080					1218	61.0	60.5	2.7	1.9	29.695	100.6		5980							
14	2.00	14.00	418010	2155					1248	63.0	61.5	2.7	1.9				5965							
15	:20	15.00	418935	2417					1280	68.7	61.5	2.7	1.85		110.3		5865							
16	:40	10.00	419970	1922			Cleaned and Poked Fire		1080	69.2	62.5	2.7	1.8		107.0		5770							
17	3:00	Overflowed ?	420795	2090					1120	71.0	65.7	2.8	1.8		101.0		5665							
18	:20	5.50	421690	2120					1200	79.0	64.7	2.8	1.75		114.4	120.0	5760	8.1	0	.4	22.5	12.6	0	56.4
19	:40	13.50	422600	2160					1218	77.0	69.0	2.8	1.8		108.0		5620							
20	4:00	16.00	423525	2110					1227	71.7	69.0	2.8	1.7		112.5		5250							
21	:20	15.00	424430	2062					1248	72.7	64.7	2.8	1.5		118.5		5250							
22	:40	17.50	425315	2040			Cleaned and Poked Fire		1280	78.0	65.6	2.8	1.5			113.0	6035	9.2	0	0	18.4	14.4	0	58.0
23	5:00	17.50	426190	2075					822	85.0	63.6	3.0	2.0		106.0		5720							
24	:20	8.00	427080	2020					1120	83.0	66.2	2.9	1.8		113.0		4675							
25	5:40	12.50	427945		382	382	Cleaned and Poked Fire	115.5	1218	8.30	63.6	2.9	1.2			111.3	5770	8.0	0	0	22.4	9.9	0	58.5
AVERAGE OR TOTAL		276.50		50809		582			1160	79.1	63.2	3.43	1.53		111.7	123.8	5670	7.9	0	.08	22.1	13.9	0	51.3

	12.79		Tests	
38. Sulphur, (separately determined)	0.83			
Ultimate Analysis of Dry Coal.				
39. Carbon	78.50			
40. Hydrogen	2.09			
41. Nitrogen	2.37			
42. Oxygen		Same Coal For All		
43. Sulphur	0.89		Tests	
44. Ash	12.79			
45. Moisture in sample as received	3.36			
Analysis of Ash and Refuse				
Air.				
82. Total apparent (a) cubic feet, (b) pounds				
83. Percentage of moisture				
84. Total dry air, (a) st'd cubic feet, (b) pounds				
85. Dry air, st'd cubic feet per 1000 cubic feet of st'd gas				
86. Dry air, st'd cubic feet per pound of dry coal fired				
Efficiency.				
87. Of producer (= heat delivered in gas per pound of combustible consumed - heat value of 1 lb. of combustible		.63	.835	.795
88. Of producer including grate (= heat delivered per pound of dry coal - heat value of 1 lb. of dry coal		.475	.692	.601
Heat Balance.				
Total calorific value of 1 lb. of dry coal				
1. Heat delivered in gas, B.T.U. per lb. of dry coal				
2. Heat to evaporate moisture in coal, B.T.U per lb. dry coal				
3. Heat to evaporate jacket water, B.T.U. per lb. dry coal				
4. Heat carried off in scrubber water, B.T.U. per lb. dry coal				
5. Heat carried off in jacket overflow, B.T.U. per lb. dry coal				
6. Loss due to incomplete combustion, B.T.U. per lb. dry coal				
7. Loss due to radiation, etc., and unaccounted for				

Test Number

Purpose of Test

At

Conducted by

In charge of Test

Plant

Kind of Boiler

Kind of Furnace

Grate surface

Method of firing

Fuel

1. Date
2.

Dimensions.

1. Number of boilers
2. Diameter of boiler
3. Number of tubes
4. Length of tubes
5. Diameter of tubes
6. Area of heating surface
7. Proportion of grate-surface to heating-surface
8. Ratio of water-heating surface to grate-surface

Average Pressures.

1. Steam by gauge
2. Atmospheric pressure
3. Total pressure
4. Force of draft in inches of water
5. Force of draft in inches of air
6. Force of draft in inches of mercury

Average Temperatures.

1. Temperature of air in room
2. Temperature of air in engine-room
3. Temperature of air in boiler-room
4. Temperature of air in fire-room
5. Temperature of air entering blower
6. Temperature of air entering fan
7. Temperature of air entering heater
8. Temperature of air leaving heater
9. Temperature of air leaving apparatus
10. Temperature of air entering chimney
11. Temperature of air leaving chimney
12. Temperature of air entering boiler
13. Temperature of air leaving boiler
14. Temperature of air entering furnace
15. Temperature of air leaving furnace
16. Temperature of air entering grate
17. Temperature of air leaving ash-pit
18. Temperature of air entering apparatus
19. Temperature of air leaving apparatus
20. Temperature of air entering engine
21. Temperature of air leaving engine
22. Temperature of air entering pump
23. Temperature of air leaving pump
24. Temperature of air entering injector
25. Temperature of air leaving injector
26. Temperature of air entering fan
27. Temperature of air leaving fan
28. Temperature of air entering heater
29. Temperature of air leaving heater
30. Temperature of air entering chimney
31. Temperature of air leaving chimney
32. Temperature of air entering boiler
33. Temperature of air leaving boiler
34. Temperature of air entering furnace
35. Temperature of air leaving furnace
36. Temperature of air entering grate
37. Temperature of air leaving ash-pit
38. Temperature of air entering apparatus
39. Temperature of air leaving apparatus
40. Temperature of air entering engine
41. Temperature of air leaving engine
42. Temperature of air entering pump
43. Temperature of air leaving pump
44. Temperature of air entering injector
45. Temperature of air leaving injector
46. Temperature of air entering fan
47. Temperature of air leaving fan
48. Temperature of air entering heater
49. Temperature of air leaving heater
50. Temperature of air entering chimney
51. Temperature of air leaving chimney
52. Temperature of air entering boiler
53. Temperature of air leaving boiler
54. Temperature of air entering furnace
55. Temperature of air leaving furnace
56. Temperature of air entering grate
57. Temperature of air leaving ash-pit
58. Temperature of air entering apparatus
59. Temperature of air leaving apparatus
60. Temperature of air entering engine
61. Temperature of air leaving engine
62. Temperature of air entering pump
63. Temperature of air leaving pump
64. Temperature of air entering injector
65. Temperature of air leaving injector
66. Temperature of air entering fan
67. Temperature of air leaving fan
68. Temperature of air entering heater
69. Temperature of air leaving heater
70. Temperature of air entering chimney
71. Temperature of air leaving chimney
72. Temperature of air entering boiler
73. Temperature of air leaving boiler
74. Temperature of air entering furnace
75. Temperature of air leaving furnace
76. Temperature of air entering grate
77. Temperature of air leaving ash-pit
78. Temperature of air entering apparatus
79. Temperature of air leaving apparatus
80. Temperature of air entering engine
81. Temperature of air leaving engine
82. Temperature of air entering pump
83. Temperature of air leaving pump
84. Temperature of air entering injector
85. Temperature of air leaving injector
86. Temperature of air entering fan
87. Temperature of air leaving fan
88. Temperature of air entering heater
89. Temperature of air leaving heater
90. Temperature of air entering chimney
91. Temperature of air leaving chimney
92. Temperature of air entering boiler
93. Temperature of air leaving boiler
94. Temperature of air entering furnace
95. Temperature of air leaving furnace
96. Temperature of air entering grate
97. Temperature of air leaving ash-pit
98. Temperature of air entering apparatus
99. Temperature of air leaving apparatus
100. Temperature of air entering engine
101. Temperature of air leaving engine
102. Temperature of air entering pump
103. Temperature of air leaving pump
104. Temperature of air entering injector
105. Temperature of air leaving injector
106. Temperature of air entering fan
107. Temperature of air leaving fan
108. Temperature of air entering heater
109. Temperature of air leaving heater
110. Temperature of air entering chimney
111. Temperature of air leaving chimney
112. Temperature of air entering boiler
113. Temperature of air leaving boiler
114. Temperature of air entering furnace
115. Temperature of air leaving furnace
116. Temperature of air entering grate
117. Temperature of air leaving ash-pit
118. Temperature of air entering apparatus
119. Temperature of air leaving apparatus
120. Temperature of air entering engine
121. Temperature of air leaving engine
122. Temperature of air entering pump
123. Temperature of air leaving pump
124. Temperature of air entering injector
125. Temperature of air leaving injector
126. Temperature of air entering fan
127. Temperature of air leaving fan
128. Temperature of air entering heater
129. Temperature of air leaving heater
130. Temperature of air entering chimney
131. Temperature of air leaving chimney
132. Temperature of air entering boiler
133. Temperature of air leaving boiler
134. Temperature of air entering furnace
135. Temperature of air leaving furnace
136. Temperature of air entering grate
137. Temperature of air leaving ash-pit
138. Temperature of air entering apparatus
139. Temperature of air leaving apparatus
140. Temperature of air entering engine
141. Temperature of air leaving engine
142. Temperature of air entering pump
143. Temperature of air leaving pump
144. Temperature of air entering injector
145. Temperature of air leaving injector
146. Temperature of air entering fan
147. Temperature of air leaving fan
148. Temperature of air entering heater
149. Temperature of air leaving heater
150. Temperature of air entering chimney
151. Temperature of air leaving chimney
152. Temperature of air entering boiler
153. Temperature of air leaving boiler
154. Temperature of air entering furnace
155. Temperature of air leaving furnace
156. Temperature of air entering grate
157. Temperature of air leaving ash-pit
158. Temperature of air entering apparatus
159. Temperature of air leaving apparatus
160. Temperature of air entering engine
161. Temperature of air leaving engine
162. Temperature of air entering pump
163. Temperature of air leaving pump
164. Temperature of air entering injector
165. Temperature of air leaving injector
166. Temperature of air entering fan
167. Temperature of air leaving fan
168. Temperature of air entering heater
169. Temperature of air leaving heater
170. Temperature of air entering chimney
171. Temperature of air leaving chimney
172. Temperature of air entering boiler
173. Temperature of air leaving boiler
174. Temperature of air entering furnace
175. Temperature of air leaving furnace
176. Temperature of air entering grate
177. Temperature of air leaving ash-pit
178. Temperature of air entering apparatus
179. Temperature of air leaving apparatus
180. Temperature of air entering engine
181. Temperature of air leaving engine
182. Temperature of air entering pump
183. Temperature of air leaving pump
184. Temperature of air entering injector
185. Temperature of air leaving injector
186. Temperature of air entering fan
187. Temperature of air leaving fan
188. Temperature of air entering heater
189. Temperature of air leaving heater
190. Temperature of air entering chimney
191. Temperature of air leaving chimney
192. Temperature of air entering boiler
193. Temperature of air leaving boiler
194. Temperature of air entering furnace
195. Temperature of air leaving furnace
196. Temperature of air entering grate
197. Temperature of air leaving ash-pit
198. Temperature of air entering apparatus
199. Temperature of air leaving apparatus
200. Temperature of air entering engine
201. Temperature of air leaving engine
202. Temperature of air entering pump
203. Temperature of air leaving pump
204. Temperature of air entering injector
205. Temperature of air leaving injector
206. Temperature of air entering fan
207. Temperature of air leaving fan
208. Temperature of air entering heater
209. Temperature of air leaving heater
210. Temperature of air entering chimney
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997. Temperature of air leaving ash-pit
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1000. Temperature of air entering engine

Fuel.

1. Size and condition
2. Weight of wood used in lighting fire
3. Coal as received
4. Weight of coal as fired
5. Moisture in coal
6. Weight of dry coal fired
7. Total ash and refuse
8. Coal per hour per sq. ft. of grate
9. Total combustible per sq. ft. of grate
10. Percentage of ash and refuse

Proximate Analysis of Fuel.

11. Fixed carbon
12. Volatile matter
13. Moisture
14. Ash
15. Sulphur, (separately determined)

Ultimate Analysis of Fuel.

16. Carbon
17. Hydrogen
18. Nitrogen
19. Oxygen
20. Sulphur
21. Ash
22. Moisture in sample tested

Analysis of Ash.

23. Silica
24. Iron
25. Lime

Analysis of Flue-gases.

26. Carbon dioxide, CO_2
27. Oxygen, O
28. Carbon monoxide, CO
29. Hydrogen, H
30. Hydrocarbons, C_nH_m
31. Nitrogen, N (by difference)

Calorific Power of Fuel.

32. B.T.U. per lb. of dry coal, Mahler's bomb calorimeter
33. B.T.U. per lb. of dry coal, Berthelot-Mahler calorimeter
34. B.T.U. per lb. of combustible
35. B.T.U. per lb. of coal as fired

Available Heat.

36. Dry gases, $W(t_1 - t)s$
37. Combined water, $9H(t_1 - t)s$
38. Moisture in coal, $w(t_1 - t)s$
39. Moisture in steam, $w_1(t_1 - t)s$
40. Unburned hydrocarbons
41. Unaccounted for and radiation, by difference

Combustible per Unit of Fuel.

42. Combustible per lb. of dry coal, Mahler's bomb calorimeter
43. Combustible per lb. of dry coal, Berthelot-Mahler calorimeter
44. Combustible per lb. of coal as fired
45. Combustible per lb. of combustible

Coal per Unit of Grate (or Heating Surface).

46. Total
47. Per hour
48. Per pound of coal as fired
49. Per pound of combustible
50. Per pound of volatile
51. Per square foot of grate surface per hour

Jacket-Water.

52. Total pounds
53. Pounds per 100 cubic feet of air delivered
54. Pounds per pound of dry coal fired
55. Total overflow, pounds

Scrubber Water.

56. Total pounds
57. Pounds per 100 cubic feet of air delivered
58. Pounds per pound of dry coal fired

Air.

59. Total pressure, (a) in inches of water, (b) in pounds
60. Percentage of moisture
61. Total dry air, (a) per hour, (b) per lb. of dry coal
62. Dry air, std. cubic feet per lb. of dry coal
63. Dry air, std. cubic feet per sq. ft. of grate per hour

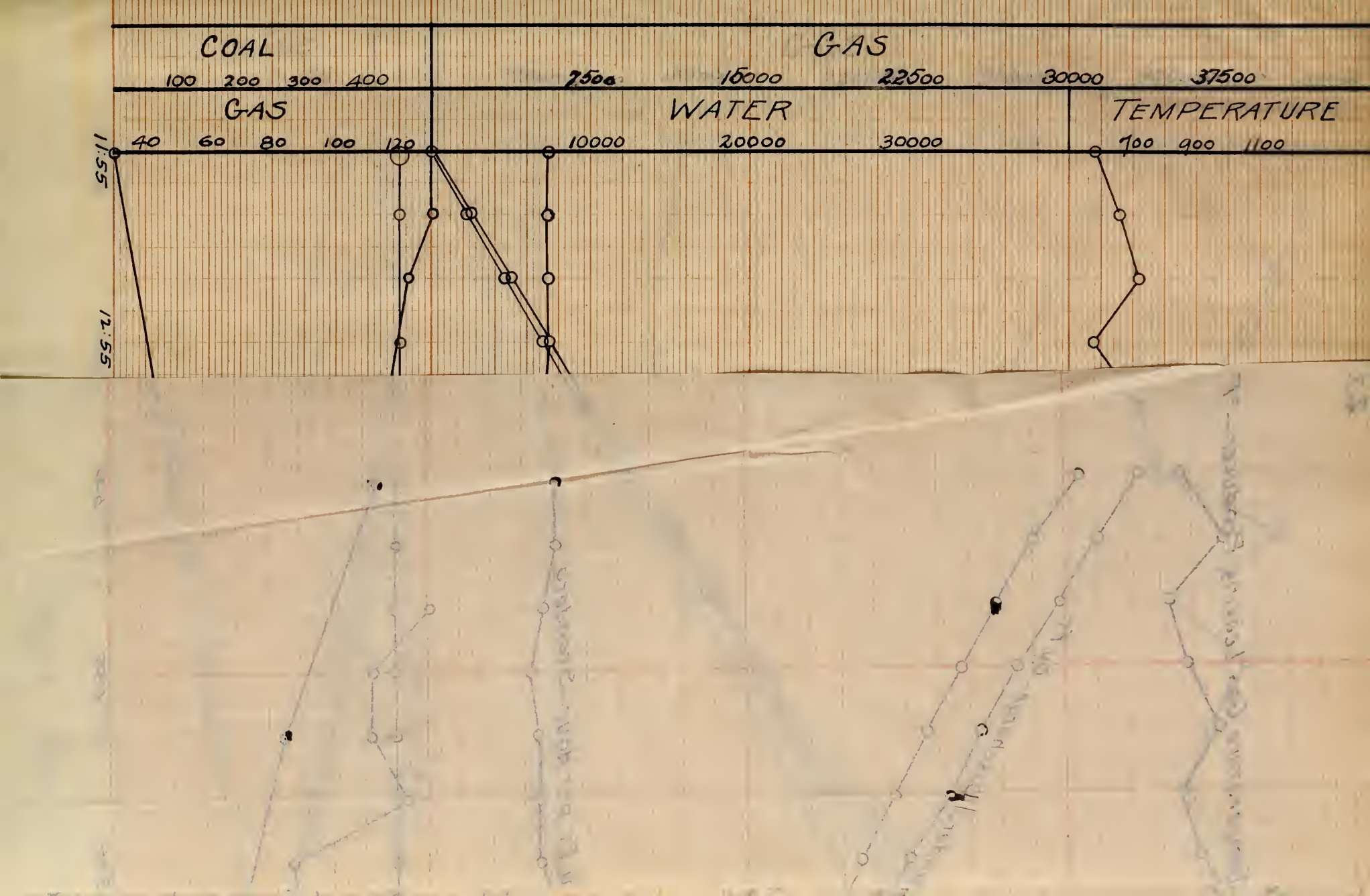
Efficiency.

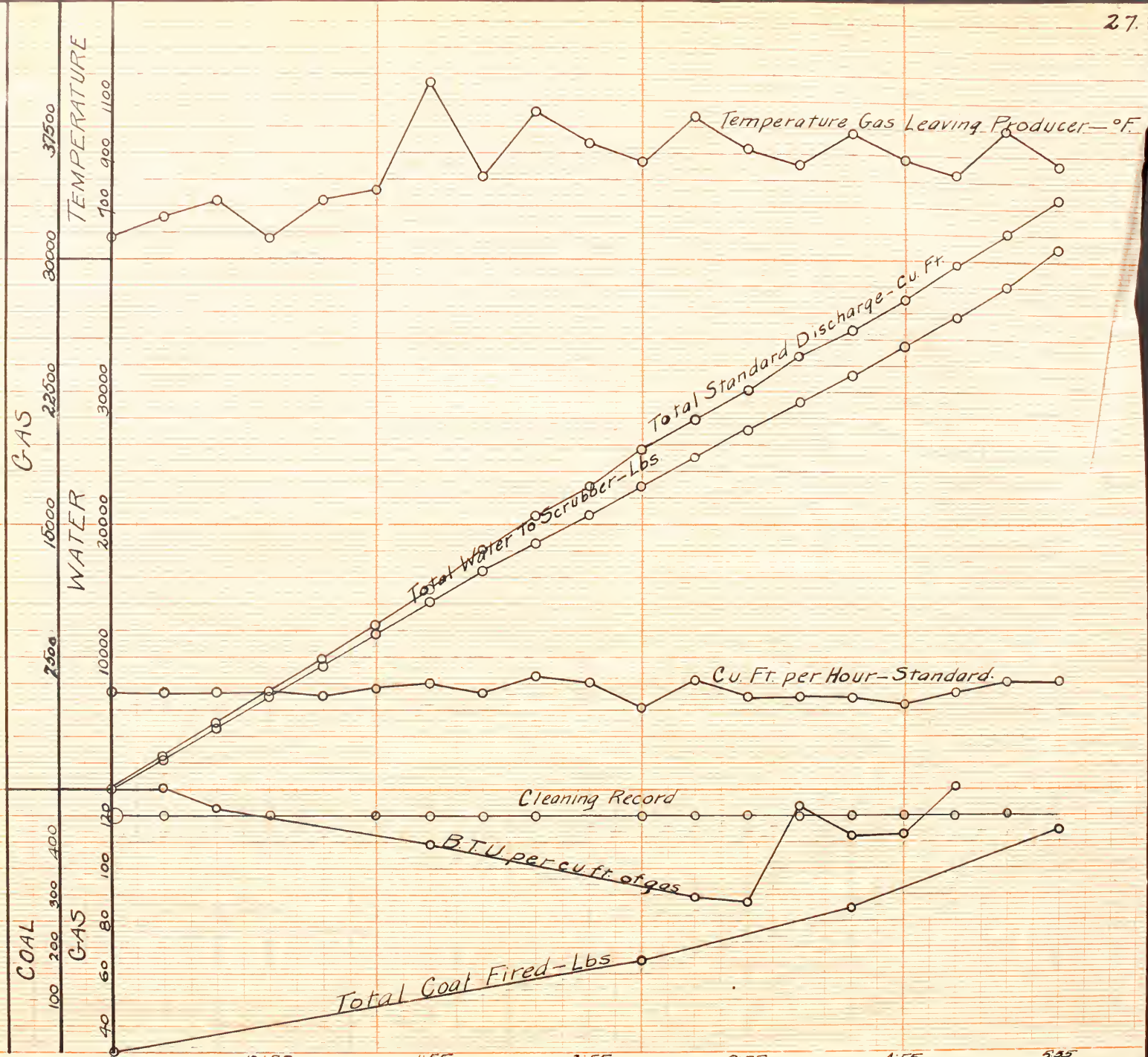
64. Of air-heater (= heat delivered to air per lb. of dry coal ÷ available heat per lb. of dry coal)
65. Of producer (= heat value of 1 lb. of combustible ÷ heat value of 1 lb. of dry coal)
66. Of producer and air-heater (= heat delivered to air per lb. of dry coal ÷ heat value of 1 lb. of dry coal)

Heat Balance.

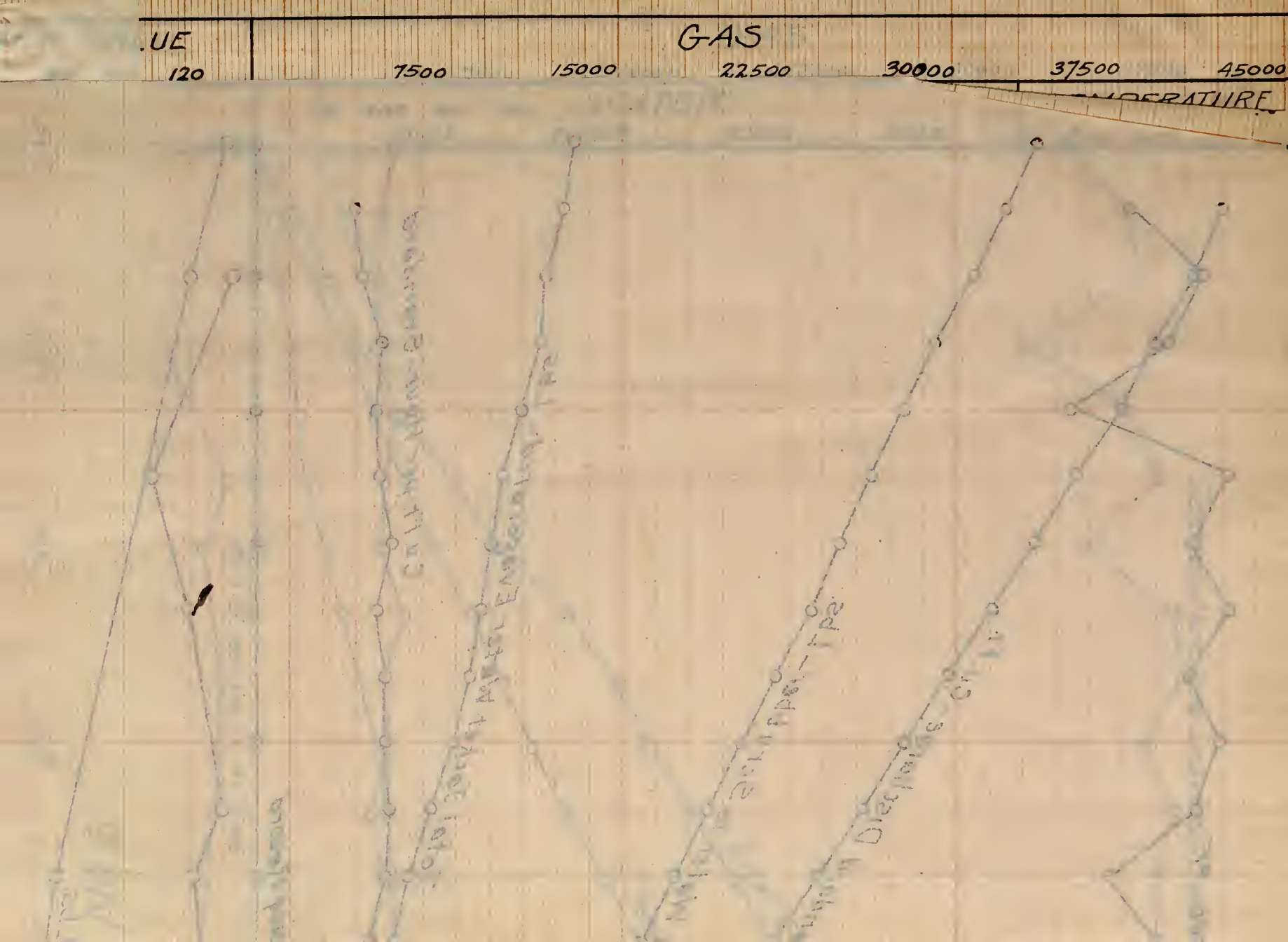
Per calorific value of 1 lb. of dry coal

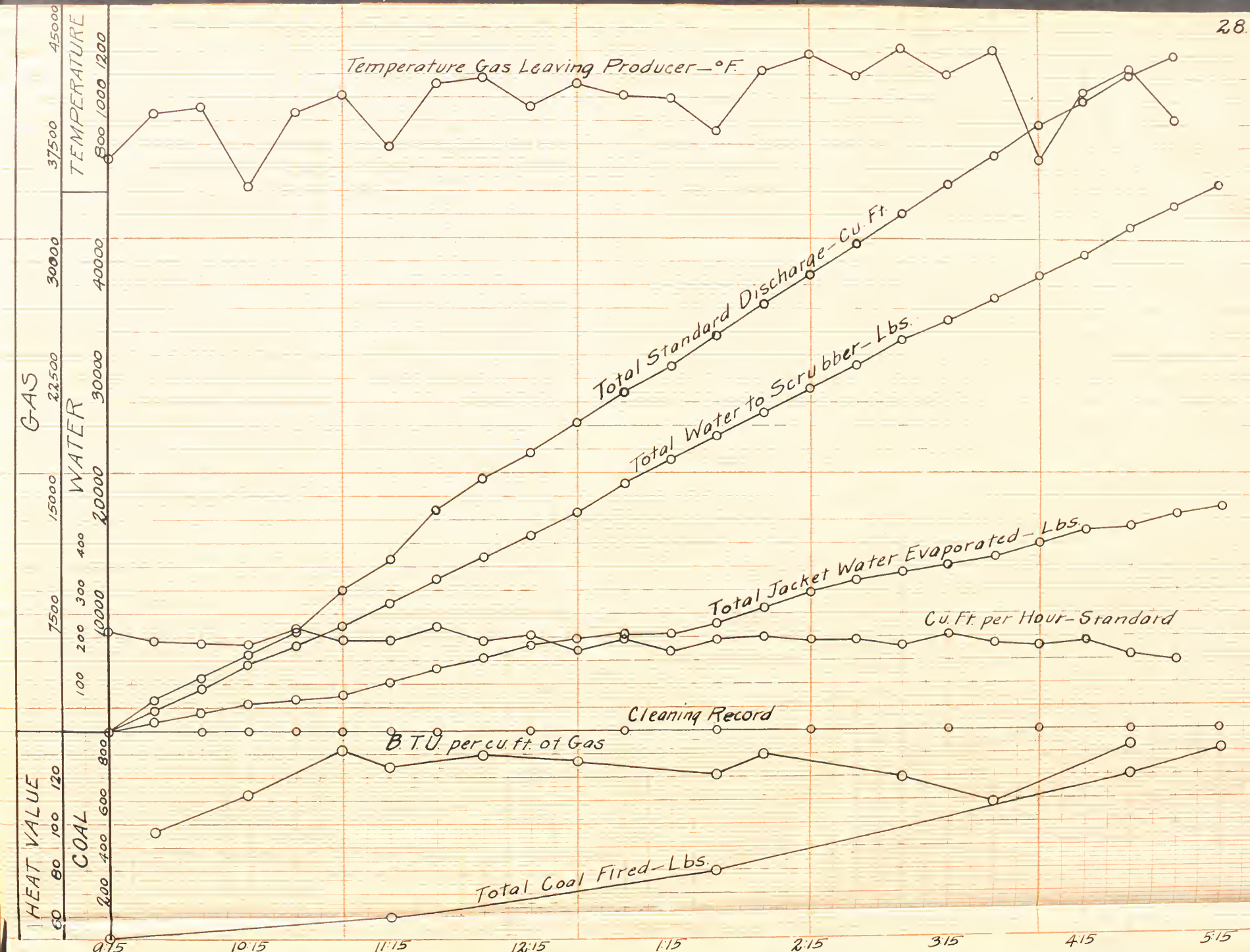
1. Heat delivered to air, $W(t_1 - t)s$, less $w_1(t_1 - t)s$, less $w(t_1 - t)s$
2. Heat to evaporate moisture in coal, $w(966 + 0.48(t_1 - t))$
3. Heat to evaporate moisture in steam, $w_1(966 + 0.48(t_1 - t))$
4. Heat carried off in superheated water from jacket, $w_2(t_2 - t)$
5. Heat carried off in superheated vapor, $W_1(t_1 - t)s$, less $w_1(t_1 - t)s$
6. Loss due to incomplete combustion, $W_2 \times 10{,}160$
7. Loss due to radiation, etc., and unaccounted for


COAL
100 200 300 400
GAS
40 60 80 100 120
GAS
7500 15000 22500 30000 37500
WATER
10000 20000 30000
TEMPERATURE
700 900 1100
11:55
12:55

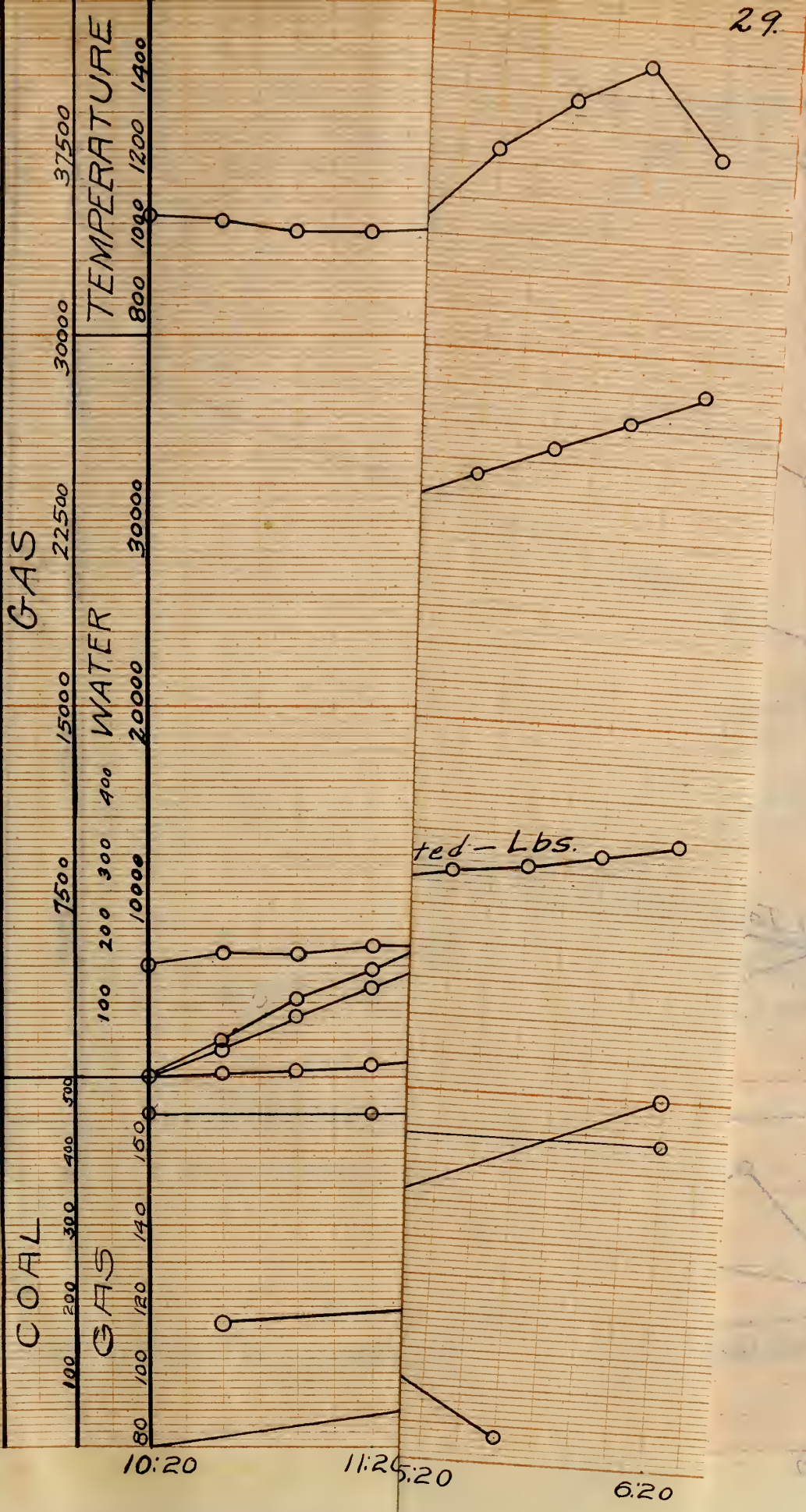

TEMPERATURE
GAS
WATER
COAL
GAS
Temperature Gas Leaving Producer — °F.
Total Standard Discharge - Cu. Ft.
Total Water To Scrubber - Lbs
Cu. Ft. per Hour - Standard.
Cleaning Record
B.T.U. per cu ft of gas
Total Coal Fired - Lbs
11:55
12:55
1:55
2:55
3:55
4:55
5:35

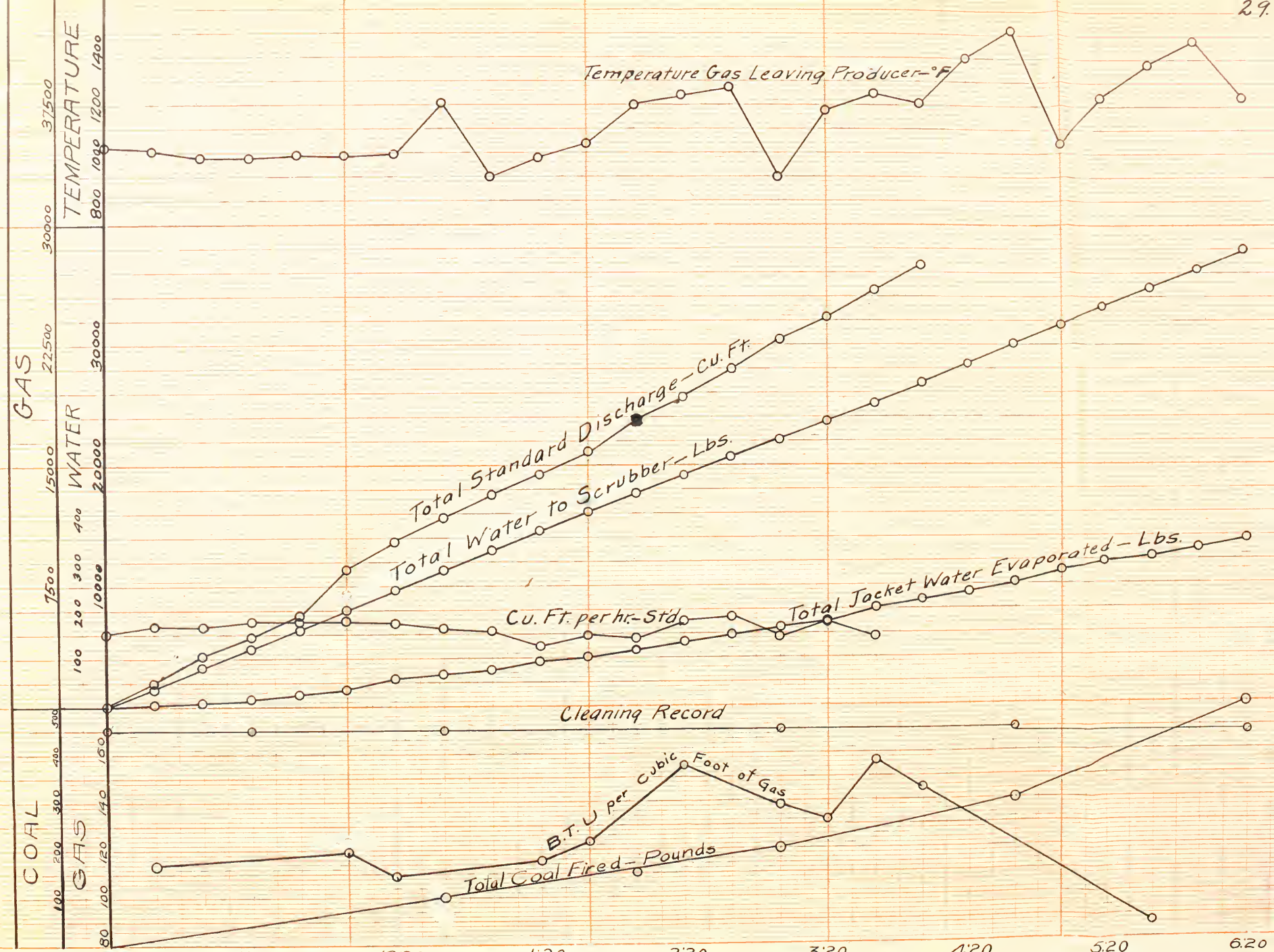
TEST No. 1.


.UE
GAS
120
7500
15000
22500
30000
37500
45000


Temperature Gas Leaving Producer—°F.
Total Standard Discharge—Cu. Ft.
Total Water to Scrubber—Lbs.
Total Jacket Water Evaporated—Lbs.
Cu. Ft. per Hour—Standard
Cleaning Record
B.T.U. per cu. ft. of Gas
Total Coal Fired—Lbs.
TEMPERATURE
GAS
WATER
HEAT VALUE
COAL
45000
37500
30000
22500
15000
7500
1200
1000
800
40000
30000
20000
10000
400
300
200
100
120
100
80
60
800
600
400
200
9:15
10:15
11:15
12:15
1:15
2:15
3:15
4:15
5:15

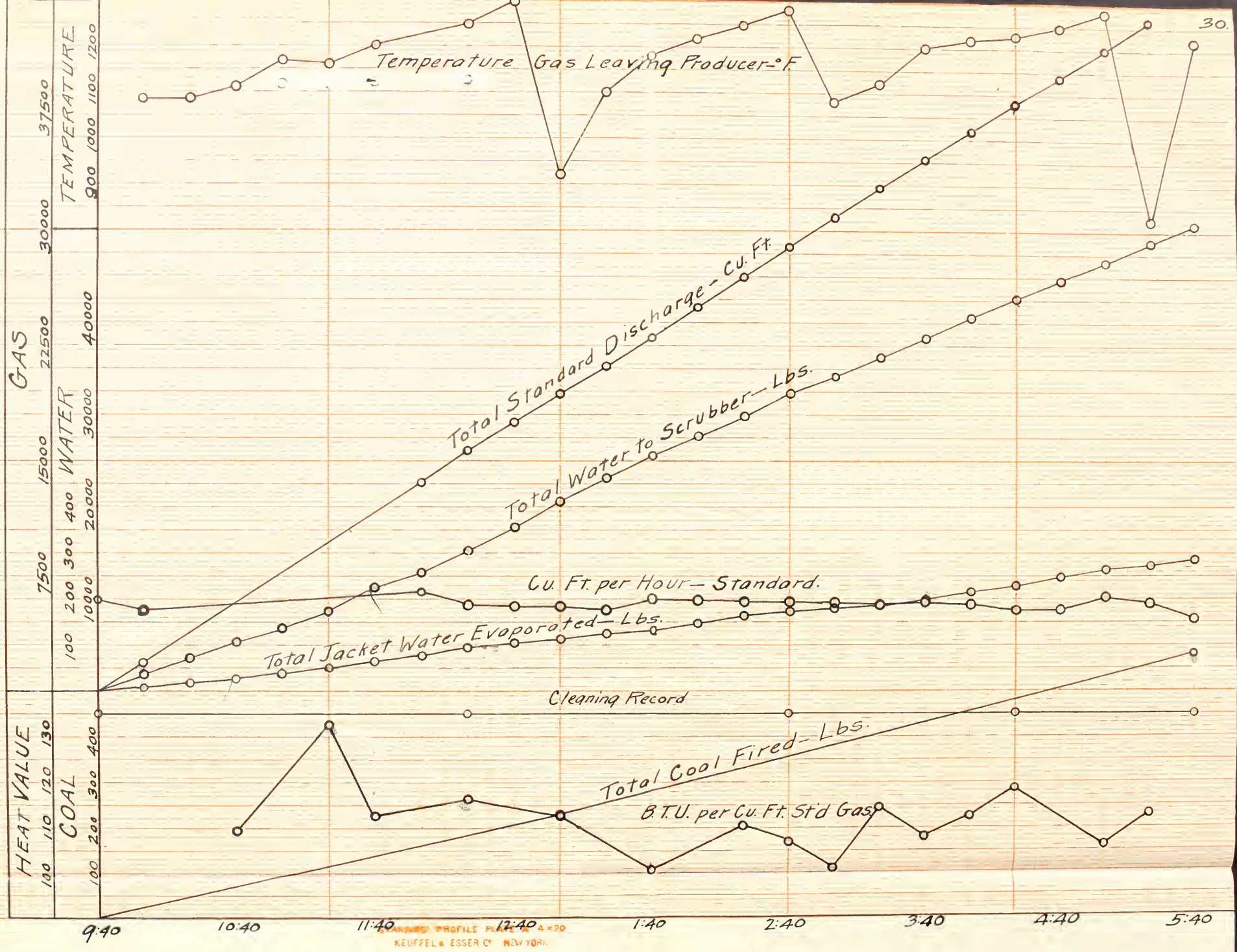
TEST NO. 2.


TEMPERATURE
800 1000 1200 1400
37500
30000
22500
15000
7500
GAS
WATER
100 200 300 400
10000
20000
30000
ted – Lbs.
COAL
GAS
100 200 300 400 500
80 100 120 140 150
10:20
11:20
5:20
6:20


Temperature Gas Leaving Producer-°F
Total Standard Discharge-Cu. Ft.
Total Water to Scrubber-Lbs.
Total Jacket Water Evaporated-Lbs.
Cu. Ft. per hr.-Std.
Cleaning Record
B.T.U. per Cubic Foot of Gas
Total Coal Fired-Pounds
TEMPERATURE
GAS
WATER
COAL
GAS
10:20
11:20
12:20
1:20
2:20
3:20
4:20
5:20
6:20

TEST No. 3.

GAS
7500
15000
22500
30000
37500



STANDARD PROFILE PLATE 4 x 20
KEUFFEL & ESSER Co NEW YORK

TEST No. 4.

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